SUMMARY OF CALFED BAY-DELTA PROGRAM ANALYSIS STRATEGY FOR WATER QUALITY ASSESSMENT VARIABLES

Seven assessment variables have been identified that will be used to evaluate and compare water quality effects of CALFED Bay-Delta Program (CALFED) alternative components. CALFED Program alternative components will directly affect several control variables (e.g., source loads of chloride from agricultural drainage, Delta outflow, contribution of Sacramento River water in exports) that will lead to changes in the assessment variables (e.g., export chloride) through a chain of relationships between one or more control variables and assessment variables.

Three of the selected assessment variables (Delta agricultural electrical conductivity [EC], export chloride [Cl], and export dissolved organic compounds [DOCs]) depend on the transport and mixing processes that occur in the Delta channels and are controlled by a combination of net flows and tidal (exchange) flows. Each of these assessment variables are also governed by concentrations in the Delta inflows (i.e., rivers, seawater intrusion, and agricultural drainage) and the contribution of these sources at the location of interest (i.e., agricultural use or export pumping). These two basic types of relationships (source concentration and source contribution) must be accurately described to allow the effects of CALFED alternative components to be properly evaluated and compared.

The disinfection byproduct (DBP) assessment variable is directly related to the export DOC and export bromide concentration, as well as the drinking-water treatment facilities and processes used. Export bromide concentration is accurately estimated as a constant fraction (0.35%) of export chloride concentration. The only remaining control variables for DBP concentration are the facilities and processes used for water treatment. Although drinking-water treatment processes are controlled by local water agencies, representative treatment processes (e.g., chlorination and ozonation) can be used to evaluate the likely changes in this assessment variable caused by CALFED alternative components

Dissolved oxygen is an assessment variable that is most important in the Stockton ship channel portion of the Delta. Dissolved oxygen is partially controlled by San Joaquin River flows past the head of Old River. Therefore, CALFED components that include a head of Old River gate or flow management on the San Joaquin River will directly affect this water quality assessment variable.

Selenium is an assessment variable that is most important in the San Joaquin River because the majority of the sources of selenium are from agricultural drainage from specific soils in the central San Joaquin River basin. The majority of the selenium load enters the San Joaquin River from Mud and Salt Sloughs, upstream of the Merced River. Tributary flows dilute and transport the selenium load to Vernalis and into the Delta. Vernalis might be used as the assessment location. Selenium concentration would be controlled by source-load reduction (e.g., land retirement or alternative drainage disposal methods) and by drainage management (i.e., seasonal storage) or flow management on San Joaquin River tributaries.

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Toxicity will be generally assessed with an index of agricultural drainage herbicide and pesticide residue concentrations that is calculated based on assumed agricultural chemical use and water management (e.g., rice water holding periods).

SUMMARY OF ANALYTICAL RELATIONSHIPS FOR EXPORT CHLORIDE CONCENTRATION

The relationships between control variables and assessment variables will be illustrated with a series of figures that are based on historical flow and EC or Cl data from the Delta.

CALFED Analytical Variables and Relationships

Assessment Variable	Supporting Variable			CALFED Action Component*
I. Physical Environment				
F. Water Quality				
1. Delta Agricultural EC (three locations)	EC at Vernalis	EC agricultural load	Agricultural acres	Land retirement, land fallowing drainage controls
		Flow at Vernalis	Tributary flows	FLOWS
	% contribution	Flow at Vernalis	Tributary flows	FLOWS
		Old River Gate		Delta gate operations
		Delta inflows		FLOWS
		Delta exports		Demand management, isolated facility
	EC at Freeport	EC agricultural load		Land retirement, land fallowing drainage controls
		Flow at Freeport	Tributary flows	FLOWS
	% contribution	Flow at Freeport		FLOWS
		Freeport diversions		DCC operation, isolated facility, Enlarged conveyance channels
		Delta inflows		FLOWS
		Delta exports		Demand management, isolated facility
	EC at Drains	Applied EC		FEEDBACK
		Evapotranspiration	Agricultural acres	Delta land conversion, Delta drainage control
	% contribution	Drainage flow	Agricultural acres	Delta land conversion, Delta drainage control
			Rainfall	INPUT
		Delta inflows		FLOWS
		Delta exports		Demand management, isolated facility
	EC at Jersey	Tidal mixing	Channel geometry	Tidal wetlands restoration, levee setbacks
		Outflow		FEEDBACK
	% contribution	Tidal mixing	Channel geometry	Tidal wetlands restoration, levee setbacks

Assessment Variable	Supporting Variable			CALFED Action Component*
F. Water Quality (continued)				
		Flow at Jersey	Exports	FLOWS
			Freeport diversions	DCC operation, isolated facility, enlarged conveyance channels
2. Export chloride (Cl) (same % contribution as Delta agricultural EC)[7]	Location			Relocate diversions
	Cl at Vernalis[2]	**Cl agricultural load[3]**	**Agricultural acres[3]**	Land retirement, land fallowing drainage controls
		Flow at Vernalis[2]	Tributary flows	FLOWS
	Cl at Freeport[1]	Cl agricultural load		Land retirement, land fallowing drainage controls
		Flow at Freeport[1]	Tributary flows	FLOWS
	Cl at drains[5]	Applied Cl		FEEDBACK
		Drainage flow[5]	Agricultural acres	Delta land conversion, Delta drainage control
			Rainfall	INPUT
	Cl at Jersey[4]	**Outflow[4]**		FEEDBACK
		Exports		FLOWS
3. Export Dissolved Organic Compounds (DOC) (same % contribution as Delta agricultural EC)	DOC at Vernalis	DOC agricultural load	Agricultural acres	Land retirement, land fallowing drainage controls
		Flow at Vernalis	Tributary flows	FLOWS
	DOC at Freeport	DOC agricultural load		Land retirement, land fallowing drainage controls
		Flow at Freeport	Tributary flows	FLOWS
	Delta DOC load	Applied DOC		FEEDBACK
		Agricultural drainage DOC	Agricultural peat soils	Delta land conversion, Delta drainage control
			Vegetation	Wetland restoration, riparian restoration
			Rainfall	INPUT
	DOC at Jersey	Outflow		
		Exports		

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CALFED Analytical Variables and Relationships

Assessment Variable	Supporting Variable			CALFED Action Component*
F. Water Quality (continued)				
		Vegetation DOC	Vegetation acres	FEEDBACK
			Decay processes	FIXED
		Algae DOC	Primary production	FEEDBACK
			Decay processes	FIXED
4. Disinfection-by-products in treated drinking water	Export DOC			FEEDBACK
	Export br	Export Cl		FEEDBACK
	Treatment process			FIXED
5. Dissolved oxygen (DO) (Stockton)	Temperature			FIXED
	BOD sources			Discharge controls
	Primary production			FEEDBACK
	Sediment demand			FIXED
	Flows			FLOWS
	Reaeration	DO deficit		FEEDBACK
		Wind		INPUT
6. Selenium	Sources	Agricultural drainage		Land retirement
		Soils		FIXED
	Dilution	Tributary flows		FLOWS

* FIXED = relationship is assumed to not change.
INPUT = monthly hydrologic or meteorologic conditions.
FEEDBACK = relationship is addressed elsewhere in table.
FLOWS = water management control.
IFIM = Instream Flow Incremental Methodology
BMP = Best Management Practices

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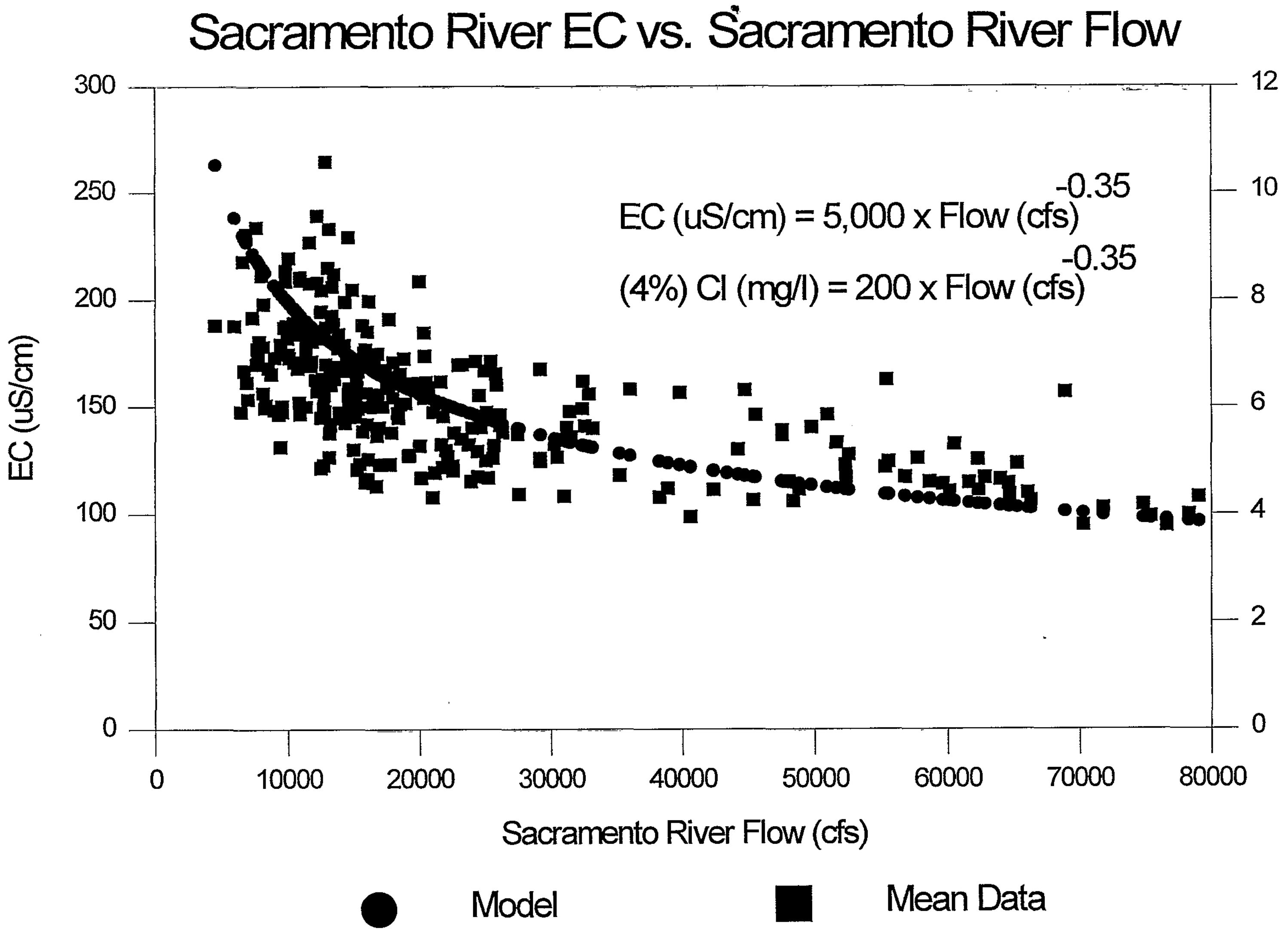
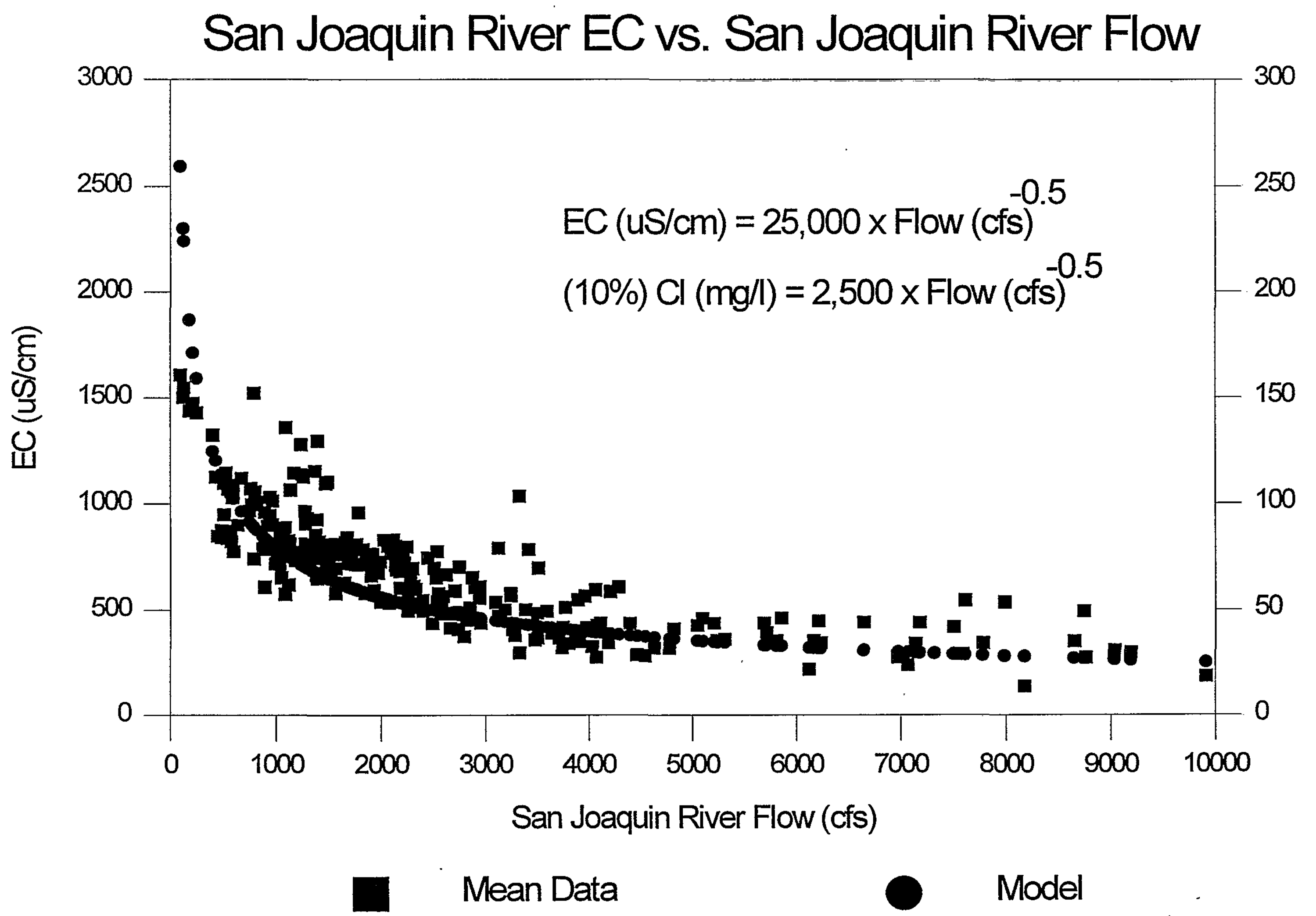
RELATIONSHIP 1

"Sacramento River EC vs. Sacramento River Flow" indicates that Sacramento River EC is relatively low, with some relationship between monthly average EC and monthly flow, but with additional variation caused by other factors. The ratio of Cl (milligrams/liter [mg/l]) to EC value (microSeimens per centimeter [μS/cm]) is approximately 0.04 (4%). This Cl/EC ratio should be illustrated with a separate analytical relationship. Sacramento River EC is almost always between 100 and 250 μS/cm; therefore, Cl concentration is almost always between 4 and 10 mg/l, which is excellent water quality. CALFED alternative components that would increase the export source contribution from the Sacramento River would, therefore, most likely improve export water quality (i.e., reduce export Cl concentration).



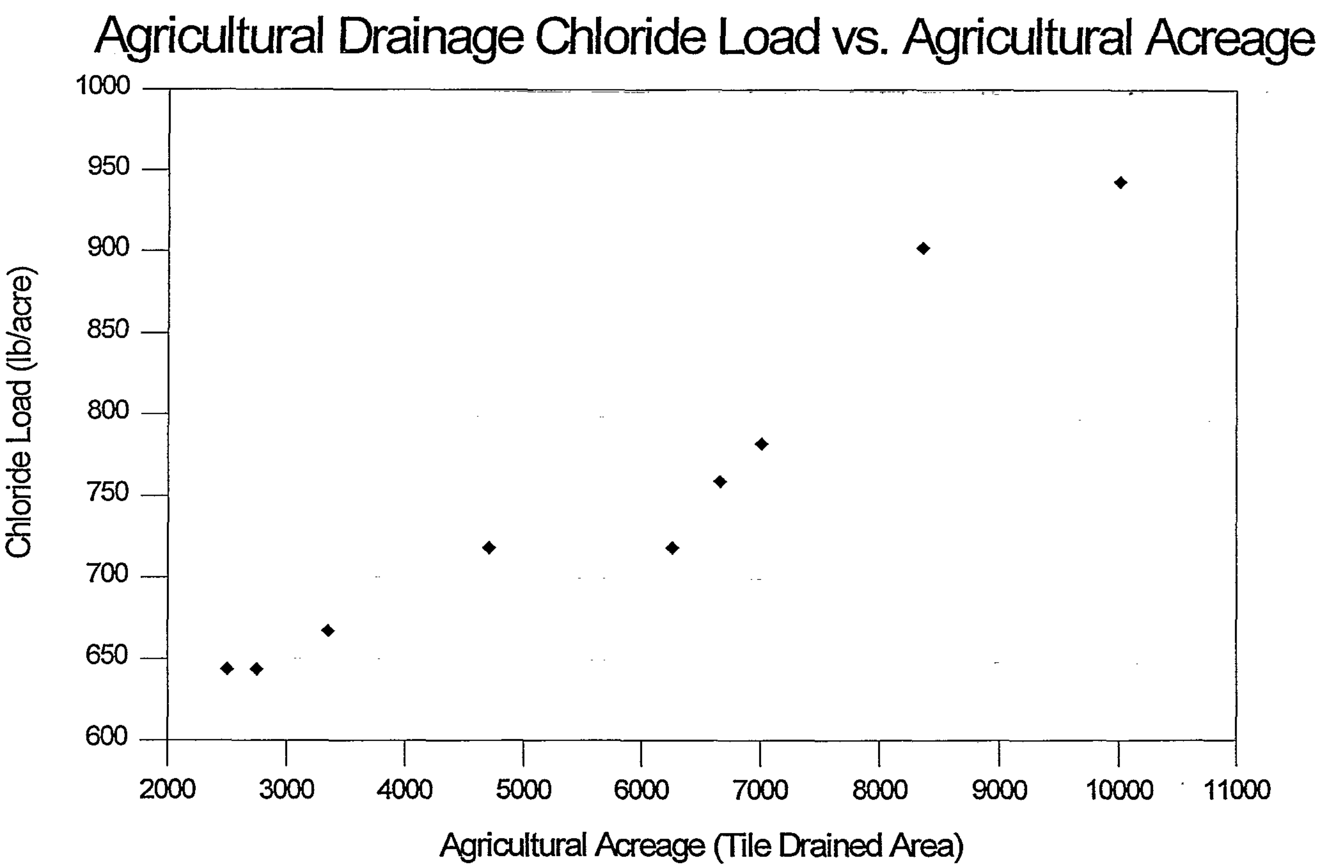
RELATIONSHIP 2

"San Joaquin River EC vs. San Joaquin River Flow" indicates that EC in the San Joaquin River is moderately high, with some relationship between monthly average EC and monthly flow, but with additional variation caused by other factors. The ratio of Cl to EC is approximately 0.10 (10%), although the Cl/EC ratio is higher (0.15) at high EC values (i.e., above 1,000 μS/cm = 1.0 milliSeimens per centimeter [mS/cm]). San Joaquin River EC is almost always between about 200 and 1,500 μS/cm; therefore, Cl concentration is usually between about 20 and 200 mg/l. CALFED Program alternative components that would decrease the Cl concentration at Vernalis (e.g., drainage management or flow management) or reduce the export source contribution from the San Joaquin River would most likely improve export water quality (i.e., reduce export Cl concentration). The San Joaquin River Input-Output Model (SJRIO) of salt loads and concentrations in the San Joaquin River might be used to estimate the changes in the Cl concentration at Vernalis as a function of flow with these CALFED Program action components.



RELATIONSHIP 3

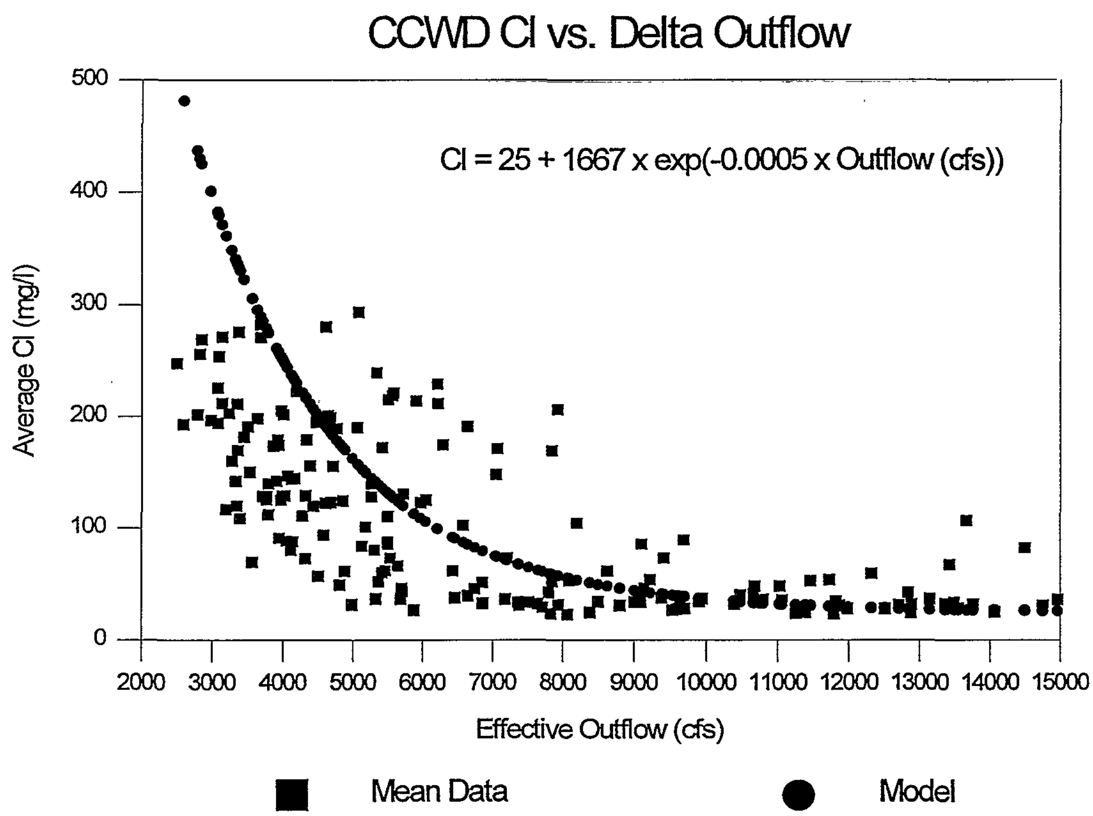
"Agricultural Drainage Cl Load vs. Agricultural Acreage" indicates that the agricultural drainage Cl load per acre will directly increase with the applied water depth times the applied water Cl concentration, and will also increase with occurrence of soil salt-leaching. Because Delta exports have a much higher Cl concentration (e.g., 100 mg/l) than the San Joaquin River tributaries (e.g., less than 10 mg/l) and because tributary water supply facilities and Delta exports have allowed expanded irrigation acreage, there has been a substantial increase in historical chloride loads discharged as drainage in the San Joaquin River. Land retirement of areas contributing the highest drainage Cl concentrations, replacement of groundwater sources that have high Cl concentrations, or reducing the export Cl concentrations would substantially improve water quality at Vernalis. An agricultural drainage model such as Westside Agricultural Drainage Economics Model (WADE) might be used to estimate effects of some of these CALFED Program alternative components on drainage volumes and Cl concentrations.



The input values for these calculations are from:
California State Water Resources Control Board (1987)
Regulation of Agricultural Drainage to the San Joaquin River, Appendix C

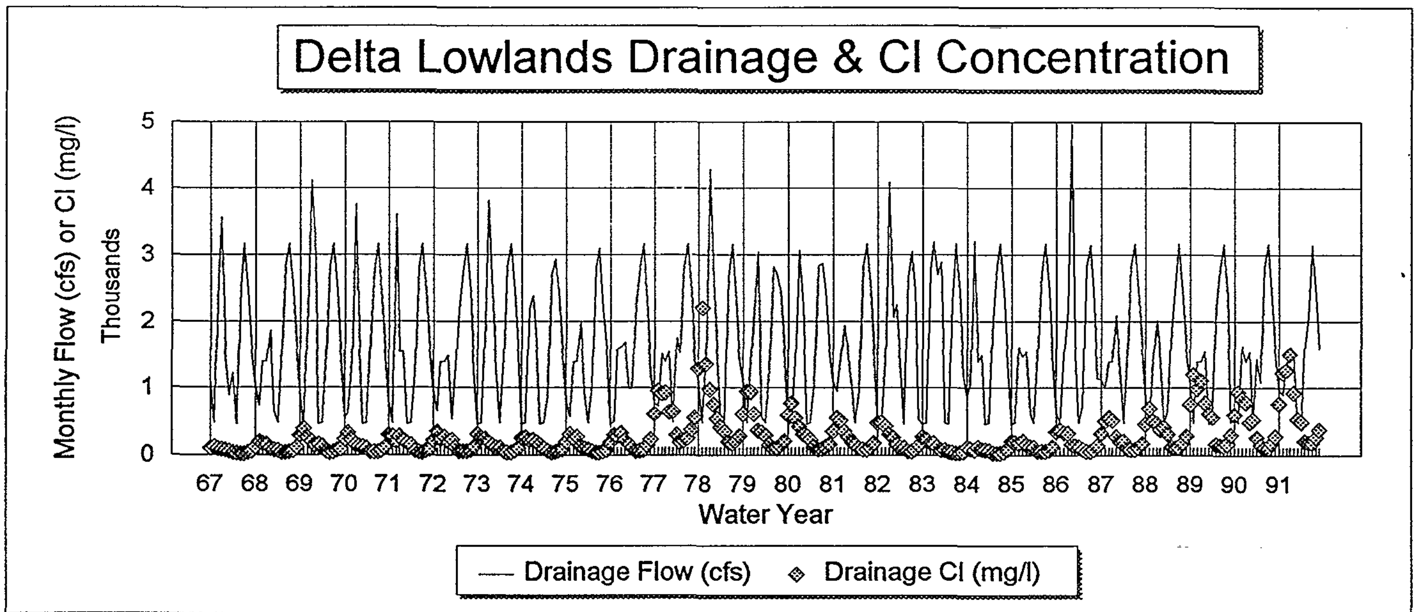
RELATIONSHIP 4

"CCWD Cl vs. Delta Outflow" indicates that monthly average seawater intrusion (i.e., the Cl concentration at Rock Slough) is directly related to the effective monthly Delta outflow (e.g., adjusted for previous month's outflow with some type of moving average). The characteristic shape of this analytical relationship for Cl at any location in the estuary is a "negative exponential" function of outflow. Because ocean Cl concentration is approximately 19,000 mg/l, very little ocean water intrusion is necessary to increase export Cl concentrations (e.g., 1% seawater would increase export Cl concentration by 190 mg/l). Monthly average historical Cl data has considerable scatter because of fluctuations in outflow and other factors within each month, but the general relationship is adequate for comparative evaluations because the causes of the variations are assumed to remain unchanged. This relationship between Cl concentration and effective Delta outflow can be summarized for the low-flow range with a negative exponential curve as shown on the figure. For example, maintaining a Cl concentration of 65 mg/l at Rock Slough would require a Delta outflow of approximately 7,000 cfs. Bromide concentrations will follow this same pattern. CALFED Program alternative components that would provide higher Delta outflows during low-flow periods (e.g., less than about 7,000 cfs) would reduce the seawater intrusion into the Delta and improve Delta agricultural and export water quality. A Delta salinity model, such as the Fischer-Delta Model or DWR's Delta Simulation Model, could be used to estimate salinity intrusion as a function of outflow for different changes in Delta geometry, such as restoration of tidal habitat or enlarged channels.



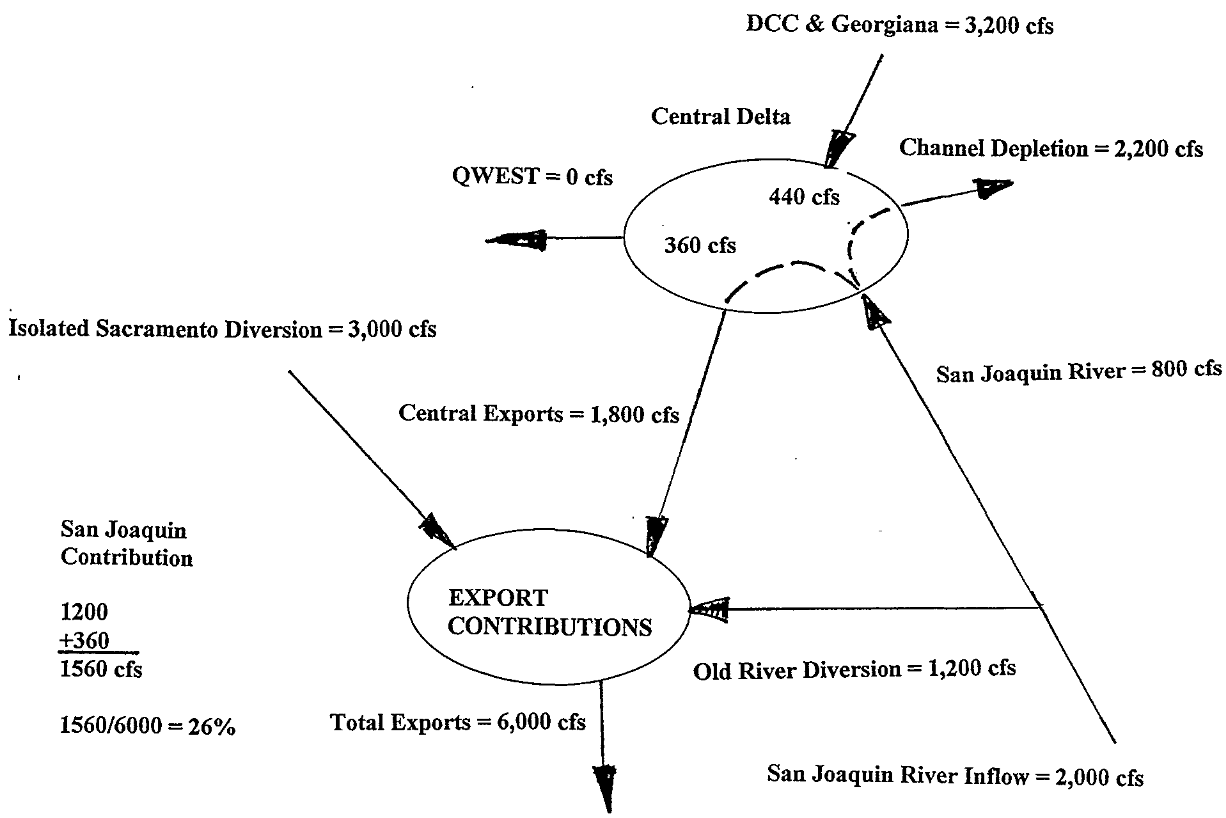
RELATIONSHIP 5

"Delta Agricultural Drainage Cl vs. Agricultural Drainage Flow" indicates that the fourth major source of Cl is from Delta agricultural drainage. Chloride in the applied water accumulates in the soil as water is lost to evapotranspiration until rainfall or leaching flushes the salts to the drainage pumps and back to the Delta channels. A water-and-salt budget model of the Delta agricultural islands, such as DWR-DSM, is necessary to accurately describe the agricultural drainage flow and Cl concentrations. A water-and-salt budget model would use calculated Delta channel Cl concentrations and assumed patterns of evapotranspiration, soil moisture requirements, and applied leaching water. By coupling the water budget and the salt budget, monthly estimates of drainage water Cl would be obtained. CALFED Program alternative components that would reduce agricultural land use in the Delta or reduce the Cl concentration of the applied water would improve Delta agricultural and export water quality.



RELATIONSHIP 6

"Contribution of San Joaquin River Water in Exports" indicates that the fraction of export water from the San Joaquin River can be estimated by considering the transport and mixing patterns in the Delta. All of the Old River diversion flow will be exported unless the exports are less than this diversion flow. The remainder of the San Joaquin River flow will be mixed in the central Delta with the eastside streams inflow, the Delta Cross Channel (DCC) and Georgiana Slough flows, and the agricultural drainage from the south and central Delta islands. The fraction of export water originating from the San Joaquin River can, therefore, be approximated from these Delta flow conditions. Isolated diversions from the Sacramento River will directly increase the contribution from the Sacramento River and decrease export pumping in the South Delta. Head of Old River diversion gate operation, San Joaquin River flow management, export pumping management, and DCC and Georgiana Slough gate operations will each have an effect on the contribution of San Joaquin River in Delta exports. A Delta hydrodynamic model can be used to simulate the contribution of each Delta water source in the Delta exports (i.e., "tracking" water). The export Cl concentration can then be calculated as the source contribution times the source Cl concentration. This is easily accomplished with a Delta water quality (salinity) model for a range of inflow conditions with different isolated diversion capacities, gate operations, and direct exports from the south Delta. The water source tracking can be approximated with a Delta channel flow model, such as DeltaSOS, that summarizes the results from a Delta hydrodynamic model with basic channel flow splits.



RELATIONSHIP 7

"Cumulative Distribution of Export Cl Concentration" indicates that the calculated export Cl concentrations for each month of a multiyear hydrologic simulation period (e.g., 1922-1991) can be summarized as the "sorted" export Cl concentrations corresponding to a particular set of CALFED Program alternative components. The advantage of using a relatively simple water quality model that estimates export Cl concentrations from the results of a water management model (i.e., with relatively few assumptions about the Cl source concentration and contribution of sources to exports) is that many different combinations of CALFED Program alternative components can be compared and evaluated.